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**Investigation of community composition on abalone (*Haliotis midae*)
shells at two sites in the Western Cape, South Africa**

BY

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THESIS PRESENTED

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
DEGREE OF MASTER OF SCIENCE IN THE DEPARTMENT OF ZOOLOGY,
UNIVERSITY OF CAPE TOWN**

UNIVERSITY OF CAPE TOWN

FEBRUARY 2010

Abstract. Algal and invertebrate assemblages resident on abalone (*Haliotis midae*) shells at two subtidal locations in the western Cape of South Africa were investigated. Forty medium-sized (linear length 10 - 20 cm) abalone were harvested (along with forty complementary rock-face quadrat samples) from one site at Cape Point and two sites at Gansbaai and the resident species were identified and statistically compared. The data revealed a high degree of diversity (Simpson's index of diversity > 0.9 for all sites and substrates), with algae providing the bulk of biomass. PERMANOVA showed each of the three sites were significantly different from each other. Multi-dimensional scaling showed a clear discrimination between communities on abalone shell and those from the surrounding rock-face. ANOSIM and SIMPER analysis pointed toward algal-defined communities. The prominence of one encrusting algae, *Mesophyllum engelhartii*, on abalone shells versus another, *Heydrichi woelkerlingii*, on adjacent rock-face, emerged as a distinguishing difference. The hypothesis that communities on abalone shells will have greater diversity was not supported. However, this study does indicate the presence of distinctive communities on abalone shells, which add to overall benthic diversity. Additionally, this work highlights that the decline of a single species can have far-reaching and community-wide implications.

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1. Introduction

The relative importance of individual species in influencing community composition has been central to much research in ecology, and the idea that particular species can disproportionately affect diversity and composition has a solid empirical basis (Paine 1966, 1969; Duggins, 1980; Menge *et al.*, 1995). In marine systems community-wide impacts have been shown to arise from changes in abundance of individual species (Estes *et al.*, 1998; Scheffer *et al.*, 2005). In South Africa, heavy poaching of the economically important abalone (*Haliotis midae*) has severely reduced its abundance (Hauck and Sweid, 1999). Investigating the abalone in terms of its impacts on community dynamics is necessary to clarify its ecological role and to predict what might happen were it to be driven to extinction.

Haliotis midae is a sub-tidal gastropod and has a range covering two-thirds of the South African coastline from Saldanha Bay to the Eastern Cape (Fig. 1). Its functional role as biogenic habitat provider is potentially of fundamental importance because of its large shell (up to 500cm²), the high densities it achieves in unharvested areas and its high longevity of up to 80 years (Gutiérrez *et al.*, 2002). Abalone may influence the community composition of surrounding rock by acting as a grazer but in this thesis I concentrate on another role it may play, namely whether it provides a unique habitat for organisms settling on its shell. Anecdotal evidence suggests the community composition on abalone shells differs from that of surrounding areas (Worm *et al.*, 2006). Thus resident communities on shells may constitute an important part of the wider sub-tidal diversity.

Haliotis midae was commercially exploited until 2007 when declining populations resulted in a complete fishing ban. However, illegal exploitation has continued to reduce abundance, with half a million abalone being confiscated from poachers yearly (Hauck and Sweijd, 1999; DEAT, 2005). Continued poaching has removed abalone from much of its range and high-density populations can be found only in isolated pockets.

Complex relationships between abalone and other subtidal species have been documented (Mayfield and Branch, 2000; Day and Branch, 2002a), and within the context of biological diversity, the loss of the abalone may have serious implications for the wider associated

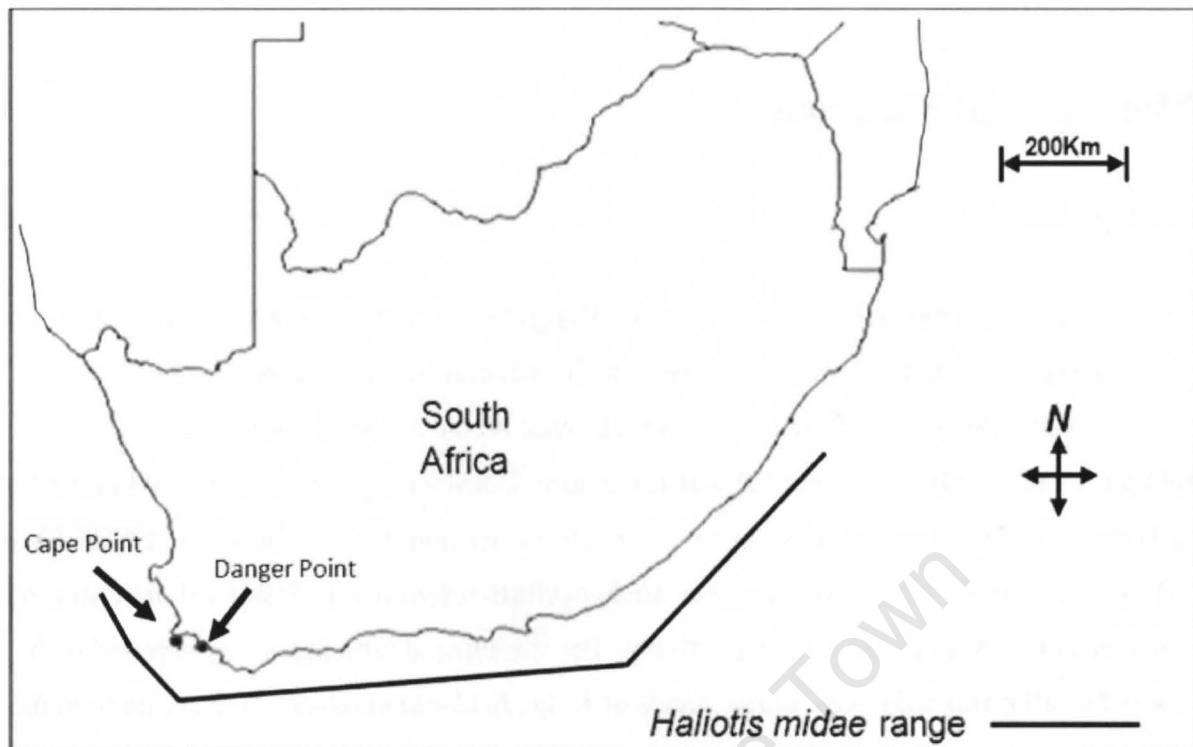


Fig. 1. Map of South Africa indicating *H. midae* sub-tidal range and the two sampling sites: Cape Point and Danger Point.

community. The objective of this research project was to document the species diversity found on abalone shells and compare it with that found on adjacent rock surfaces, to determine if abalone shells provide a unique habitat or simply house species similar to those occupying rocks.

I hypothesized that the shells of the South African abalone (*H. midae*) will have greater species diversity and distinctly different communities relative to those growing on adjacent rocks.

2. Methods and Materials

2.1 Study sites

Two study areas were employed: Cape Point and Danger Point on the southwestern coast of South Africa (Fig. 2), both of which contained sufficient abalone aggregations for the study. Sampling at Cape Point ($34^{\circ}37' \text{ S}$, $19^{\circ}17' \text{ E}$) took place on the 5th April 2009. Danger Point sampling took place adjacent to the I & J abalone farm, Gansbaai, approximately 140 km east of Cape Town, in two sub-areas: Area A ($34^{\circ}37' \text{ S}$, $19^{\circ}17' \text{ E}$), and Area B ($34^{\circ}37' \text{ S}$, $19^{\circ}18' \text{ E}$) on the 29th January 2009. These two sub-areas are henceforth referred to as Danger Point (Area A) and Danger Point (Area B) (Fig. 2) respectively. The shoreline at both areas was exposed with occasional small protected coves. Large stands of Kelp (*Ecklonia maxima*) were common in the sub-tidal at both sites and *H. midae* was found at a depth range of around 2 - 6 m.

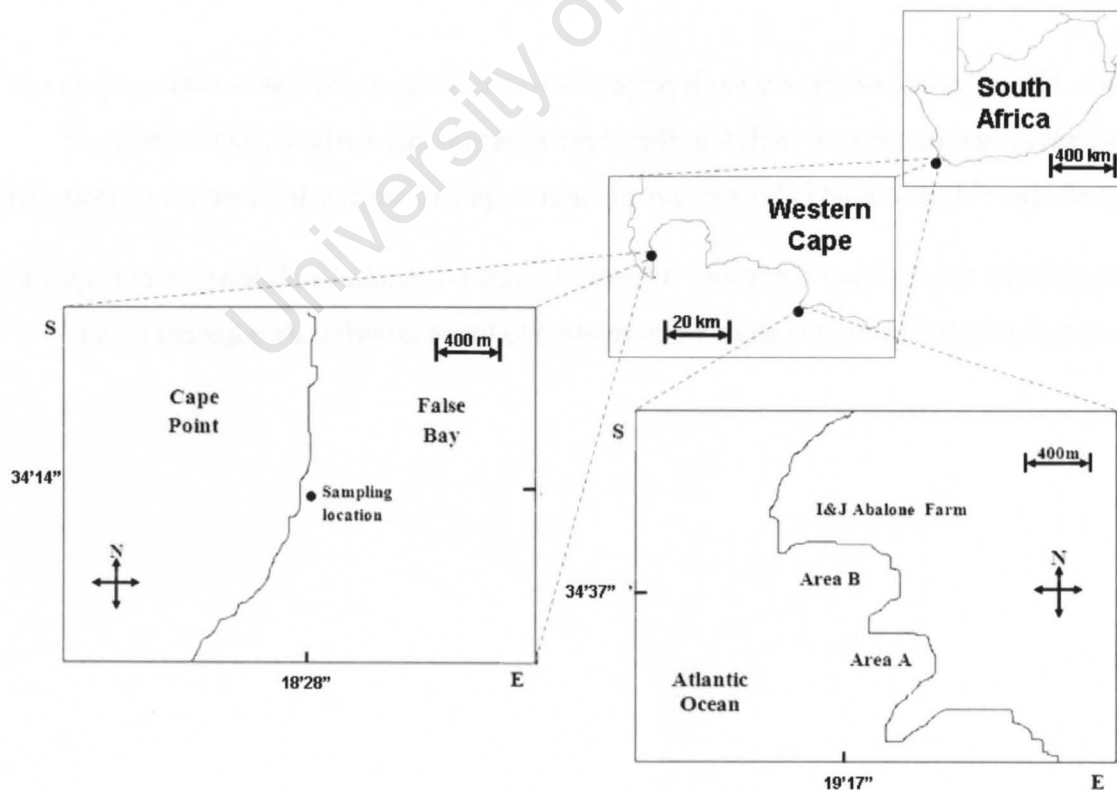


Fig. 2. Map of Cape Point indicating sampling location

2.2 Sampling design and selection process

Twenty abalone were randomly harvested from each site by SCUBA divers in the subtidal zone (depth range 2 – 4 m). Medium-sized (linear length 10 - 20 cm) abalone were selected to avoid any differences arising from changes in behaviour and habitat related to size (Tutschulte and Connell, 1988). Each abalone was placed into a plastic zip lock bag whilst underwater. For each abalone harvested, a complementary rock-face was sampled by using a flat-bladed metal scraper to remove all biota from an adjacent 20x20 cm quadrat, which approximated the area of the abalone shells. Each rock-face sample was randomly located within a 1 m radius of its paired abalone. Each rock-face sample was also placed into a zip lock bag underwater. Percentage cover of encrusting algae on rock samples surface was noted if it could not be removed.

2.3 Laboratory analysis

All abalone were measured (linear length and width and string length and width) (Fig. 3). No attempt was made to include the minor ridges which run along the top of the shells. All species were removed from the abalone shells and rock-face samples, wet-weighed and individually identified to species level where possible (Day 1969, Simons 1976, Griffiths 1978, Kensley 1978, Branch *et al.* 1995, Stegenga *et al.* 1997). Percentage cover of encrusting algae on abalone shell was recorded, and converted to biomass by assigning a value of 0.5 g per cm², derived from samples of known area. For statistical purposes where a species was in extreme low abundance a token weight of 0.05 g was used. Amphipoda and Isopoda were given a token weight of 0.1 g per specimen which was based on sub-sampling. Before statistical analysis, data for two abalone from Danger Point became corrupted and could not be included in the analysis. Their paired rock-face samples were also removed to retain balance. Differences existed between the areas of shell surfaces and rock-face samples. Given the usage of a 20 cm x 20 cm quadrat, rock-face surface area equaled 400cm² per sample. Surface areas of shells were obtained using the formula πr^2 , where $r = 0.25(\text{string length} + \text{string width})$ and averaged. String length/width was employed in preference to linear measurements to allow for the curvature of abalone shells (Fig. 3). To account for the larger surface area total of rock-face than shell samples when determining diversity, individual rock-face samples were randomly selected and removed from the data to ensure shell and rock-face samples were of equal total area. The sub-division of the Danger Point

site meant that the data was used to compare rock-face vs. shell at each site and not to compare among sites because of the different sample sizes.

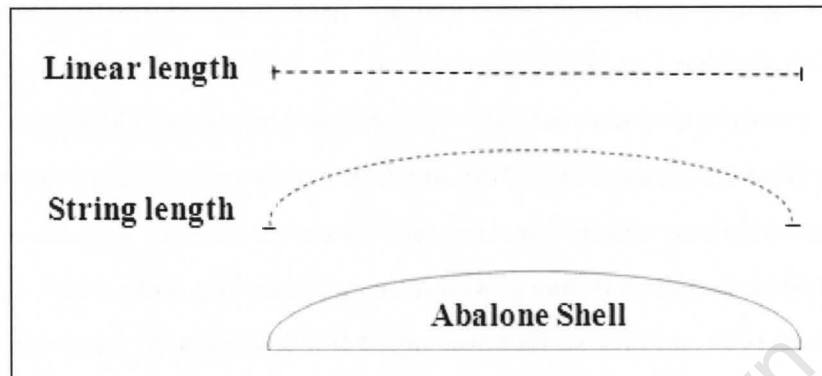


Fig. 3. Side-view of abalone shell with linear and string measurements. String distances accounted for curvature of shell and were thus a more useful measurement to calculate surface area.

2.4 Data visualization and statistical procedure

PRIMER (ver. 6.1.5, Plymouth Marine Laboratory, Plymouth, England) was used for multivariate analysis (Clarke & Warwick, 1994). A PERMANOVA analysis was carried out to assess differences between all three areas and between treatments (Shell vs. rock-face samples). Monte Carlo tests were not required, as unique permutations were consistently > 5000.

STATISTICA (ver. 8.0, StatSoft, Inc.) was used to test for significant differences in total biomass between shell and rock-face samples, and for differences in the biomass of individual species between the two habitats. Data were tested for normality using Kolmogorov-Smirnov and Levene's test was used to test for equal variance, which revealed that the average biomass of treatments were normal and of equal variance. A t-test was used to test for significant differences in biomass between habitats. Data for individual species were found to be non-normal and of unequal variance. The non-parametric Mann-Whitney test was thus used to ascertain the significance of difference for individual species, and p-level, U and Z-adjusted statistics were reported; the latter statistic being included as it accounts for the presence of equal ranked data.

PRIMER was used to perform MDS, SIMPER analysis and ANOSIM tests. Data were 4th-root transformed to reduce the effect of extreme values, then subjected to Bray-Curtis similarity

analysis. Ordination by non-metric Multi-Dimensional Scaling (MDS) was based on a dissimilarity matrix created from Bray-Curtis analysis. Simper analysis was used to determine the contribution of each species to the average Bray-Curtis dissimilarity between shell and rock-face samples. Differences between treatments were tested using an a priori one-way analysis of similarities (ANOSIM) test.

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3. Results

3.1 PERMANOVA

PERMANOVA showed that treatment (shell versus rock) had a significant effect (Pseudo=14.24, $P(\text{perm}) < 0.0001$. Cape Point shell and rock samples (Pseudo-F=15.507, $P(\text{perm}) < 0.0001$, SS=32341), and Danger Point (Area A) shell and rock-face samples (Pseudo-F=4.2974, $P(\text{perm}) < 0.0003$, SS=9485) were significantly different. However, Danger Point (Area B) shell and rock samples were marginally non-significantly different (Pseudo-F=1.724, $P(\text{perm}) = 0.0553$, SS=3914.6).

3.2 Species richness

Samples from all three locations had a large number of species (>30) (Fig. 4). Cape Point supported the largest number of unique species and the largest total number of species on both abalone shell and rock-face surfaces. At each of the three sites there was a slightly higher total number of species found on rock-face than on shell samples.

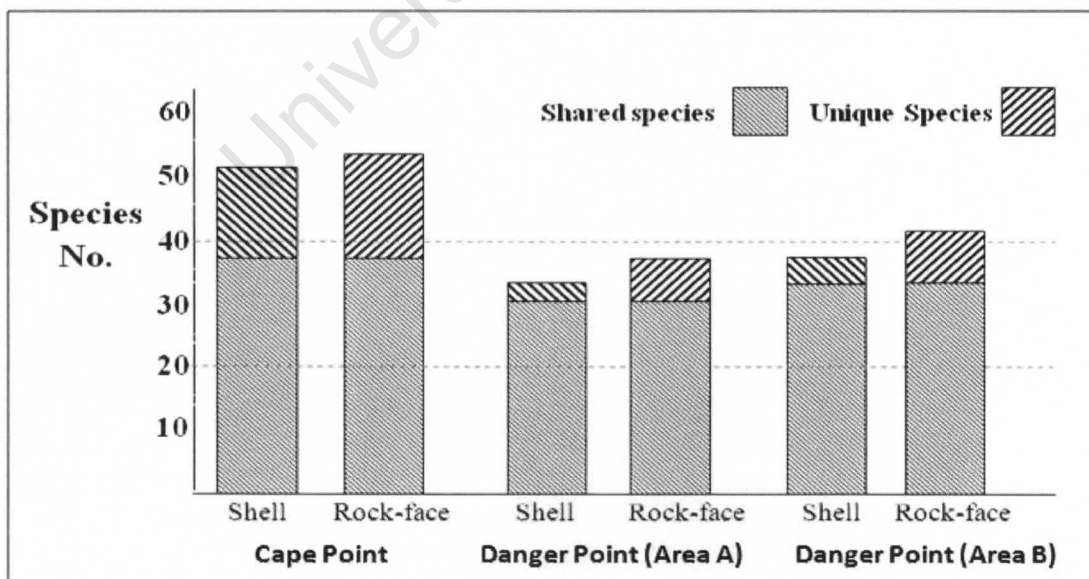


Fig. 4. Bar chart of species number on shell versus rock-face at three sites

3.3 Cape Point

3.3.1 MDS

The MDS ordination (Fig. 5) for Cape Point showed clear discrimination between the communities on the abalone shell and the rock-face (ANOSIM, $R=0.78$, $p<0.001$). SIMPER analysis revealed shell samples had a higher percentage similarity (40.52%) than rock-face samples (32.70%).

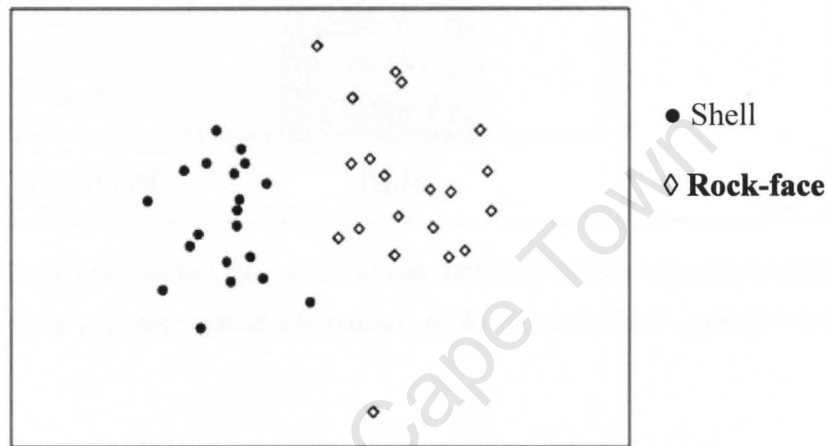


Fig. 5. Two-dimensional MDS ordination of community data found on abalone shells and rock-face at Cape Point. Each symbol represents a sample. Total $n=40$. (Stress = 0.19).

3.3.2 Diversity index

Simpson's index of diversity ($1 - D$) for both abalone shell (0.9358) and rock-face (0.952) were high, indicating a high degree of species richness and evenness. (See Appendix for detailed species list)

3.3.3 Average biomass per substratum

Average biomass was significantly higher in shell samples than rock-face samples (t -value=5.068, $df=38$, $p < 0.0001$) (Fig. 6).

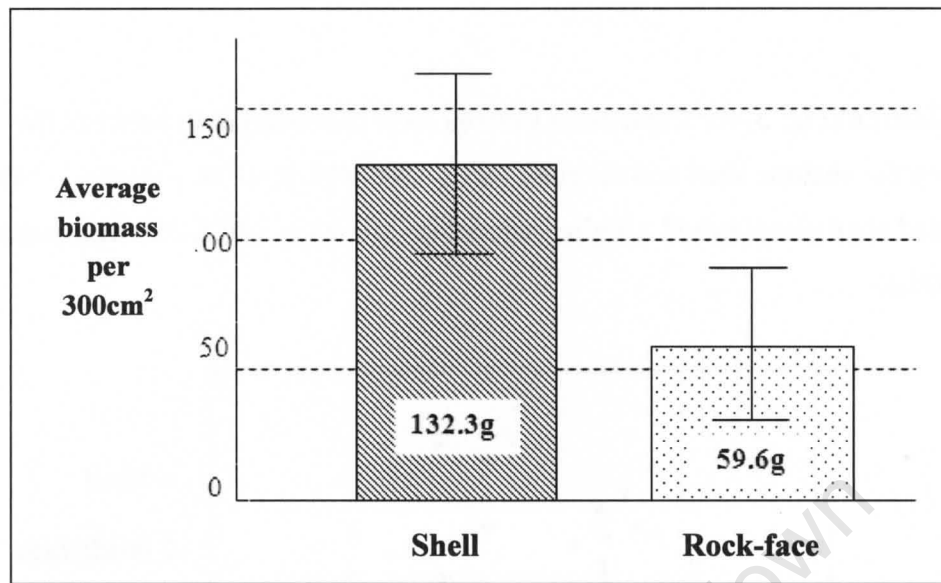


Fig. 6. Bar graph of average biomass per shell and per rock-face sampled at Cape Point. Error bars =1 SD (Shell ± 43.36 g, Rock-face ± 30.08 g). Total $n=40$. Surface area per sample = 300 cm^2 .

3.3.4 Average biomass per species

Mesophyllum engelharti, *Amphiroa capensis*, and *Arthrocardia flabellata* all had significantly more biomass in shell communities than rock-face samples (Fig. 7). In addition, two taxa, *Cheilosporum cultratum* and *Ulva* spp. were found only on shells. SIMPER comparisons showed that five species, *Mesophyllum engelhartii*, *Amphiroa capensis*, *Arthrocardia flabellata*, *Scutellastra barbara* and *Tricolia neritina* accounted for more than 80% of similarity within shell samples (Fig. 7). Seven species - *Heydrichia woelkerlingii*, *Tricolia neritina*, *Platynereis dumerilii*, *Paramoera capensis*, *Lysianassa ceratina*, *Dynamenella huttoni* and *Hyale grandicornis* accounted for 80% of similarity within rock-face samples. Consistently *Mesophyllum engelhartii*, *Heydrichia woelkerlingii*, *Amphiroa capensis* and *Arthrocardia flabellata* contributed the most to the dissimilarity between the shell and rock-face samples.

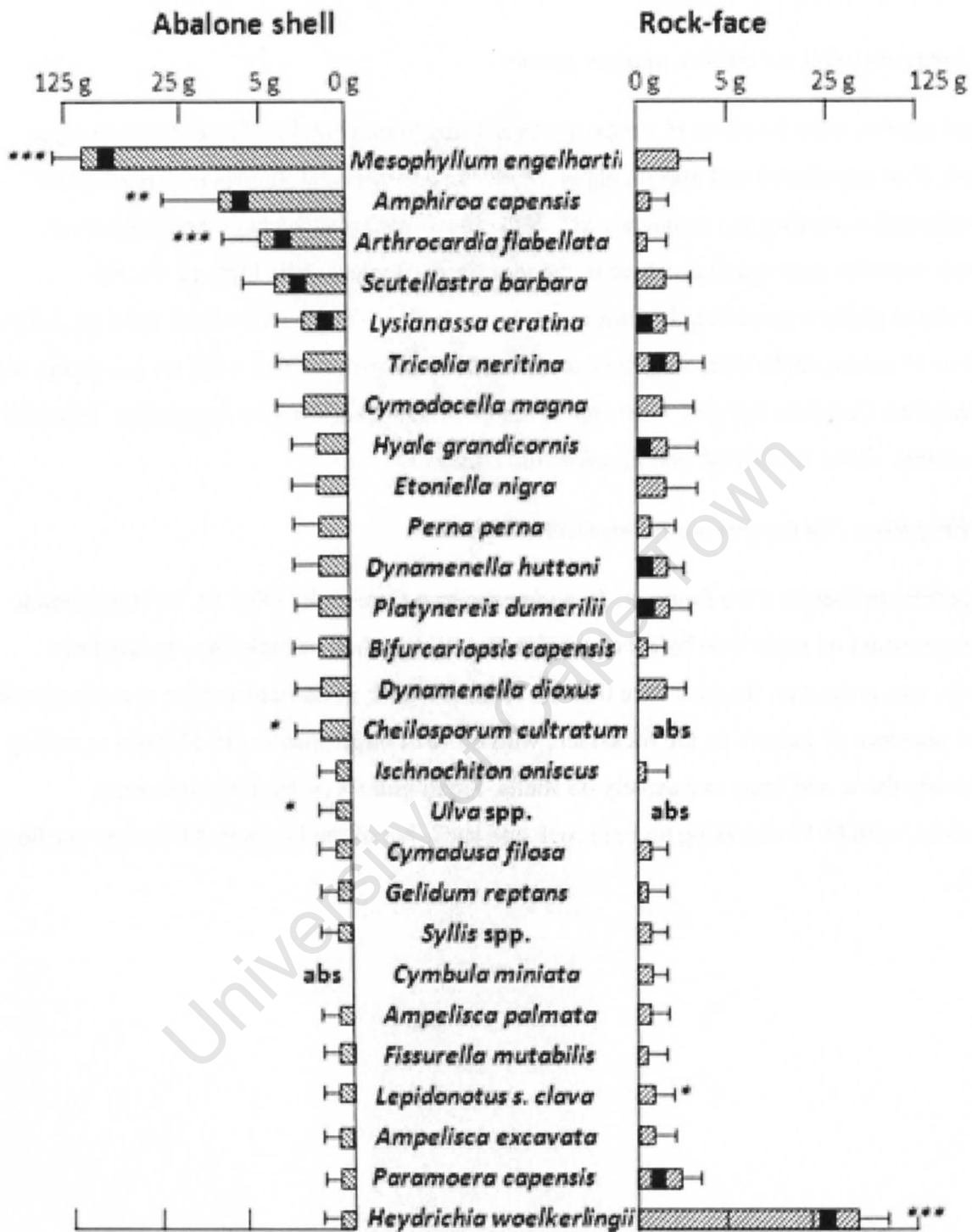


Fig. 7. Average biomass of species found in shell and rock-face samples at Cape Point. Data 4th root transformed. Black bars indicate characteristic species accounting for 80% of biomass. *** $P < 0.0001$ signif. level, ** $P < 0.001$ signif. level, * $P < 0.05$ signif. level. Error bars (+ 1 SE); abs = absent.

3.3.5 Frequency (%) occurrence of algal species

19 algal species were found on *H. midae* shells at Cape Point (Fig. 8). The encrusting algae *Mesophyllum engelhartii* and upright algae *Amphiroa capensis* and *Arthrocardia flabellata* predominated, occurring at a frequency of $\geq 70\%$. *Heydrichia woelkerlingii* and *Amphiroa capensis* were the most common algae in the rock-face samples. Rhodophyta was the predominant phylum providing the four most common algae. There were seven species of algae found on *H. midae* shells (four of which occur at $\geq 10\%$ frequency) that were not present in rock-face samples: *Gelidium reptans*, *Ulva* spp., *Cladophora sericea*, *Codium papenfussi*, *Dictylota* cf. *dicotama*, *Jania verrucosa*, and *Rhodomenia capensis*.

3.3.6 Frequency (%) occurrence of invertebrate species

23 invertebrate species were found on *H. midae* shells at Cape Point (Fig. 9). No invertebrate species occurred on more than half the samples from either shell or rock-face. Invertebrate diversity was greater on the rock-face than on abalone shells; in particular there was a noticeable greater presence of grazers on the rock-face, with 60 % of large grazers (10-60 mm) occurring exclusively there, and none exclusively on shells. Small grazers (< 10 mm) were most ubiquitous, with 66 % occurring on both rock and shell, but of the balance, 80 % were confined to rock.

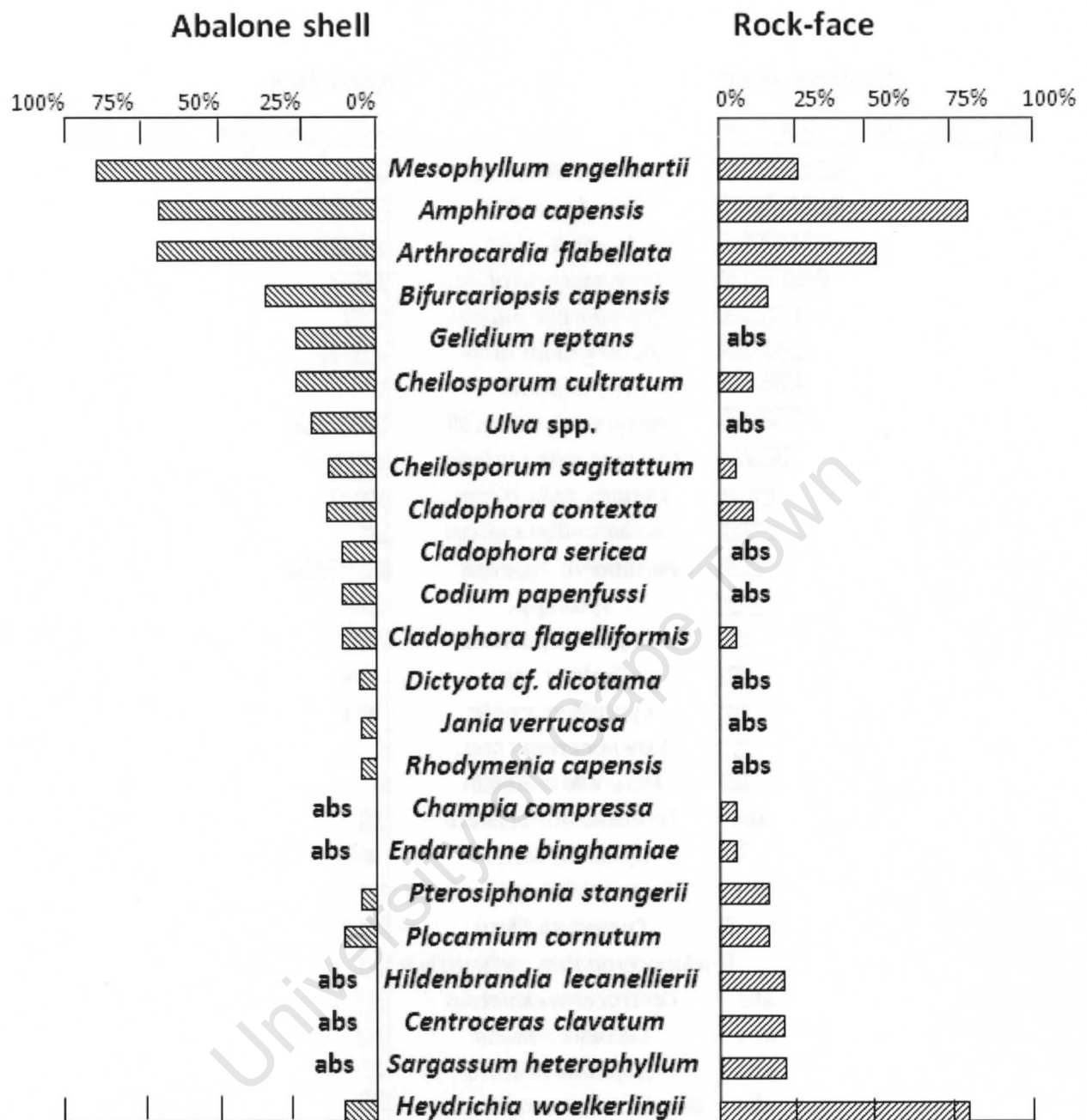


Fig. 8. Percentage frequencies of algal species found on abalone shell versus rock-face at Cape Point.

abs = absent.

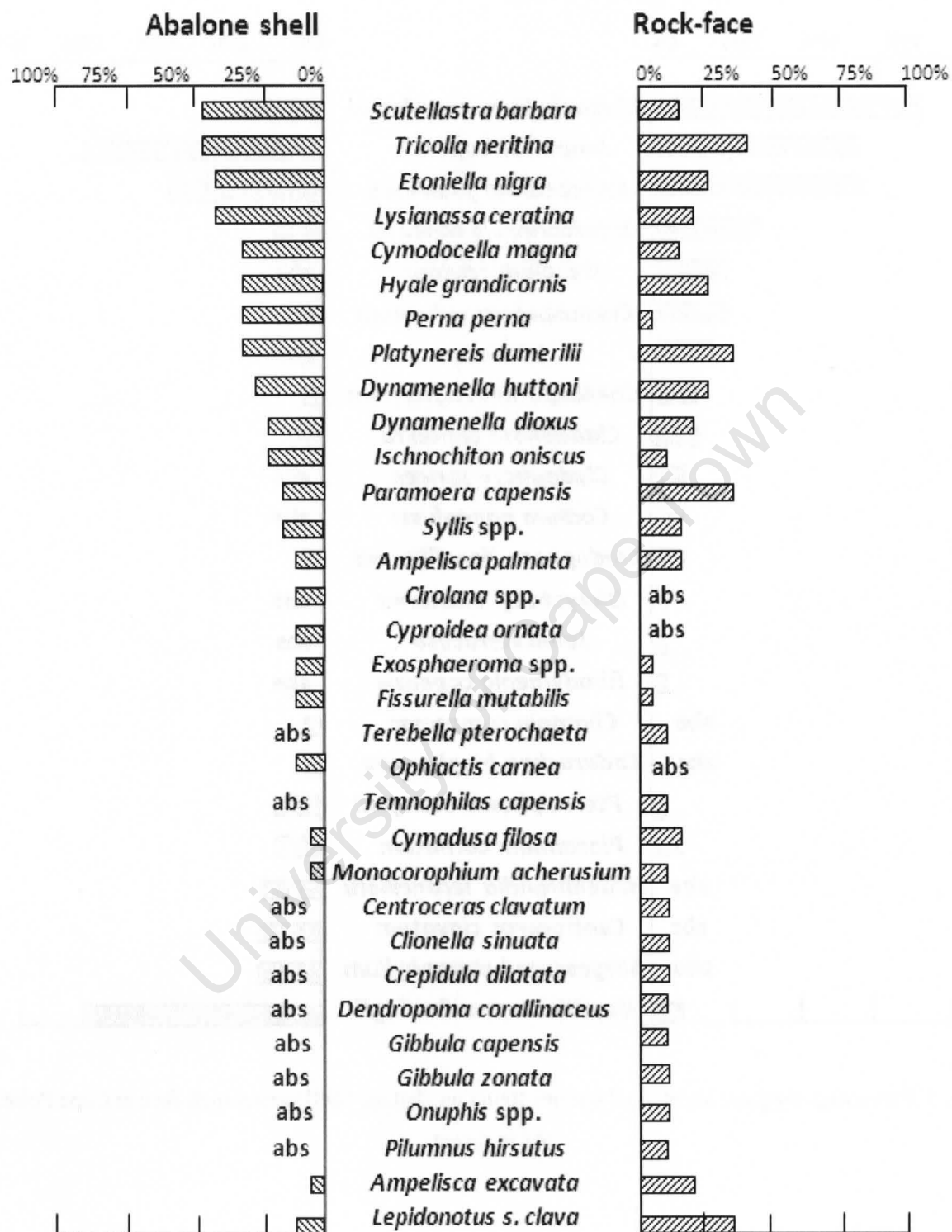


Fig. 9. Percentage frequencies of invertebrate species found on abalone shell versus rock-face at Cape Point. abs = absent.

3.4 Danger Point (Area A)

3.4.1 Multi-dimensional scaling

The MDS ordination (Fig. 10) for Danger Point (Area A) indicated closely-grouped shell communities that were significantly different to the more diffuse rock-face samples (ANOSIM, $R=0.516$, $p<0.001$). SIMPER analysis showed shell samples had a higher percentage similarity (38.23%) than rock-face samples (30.65%).

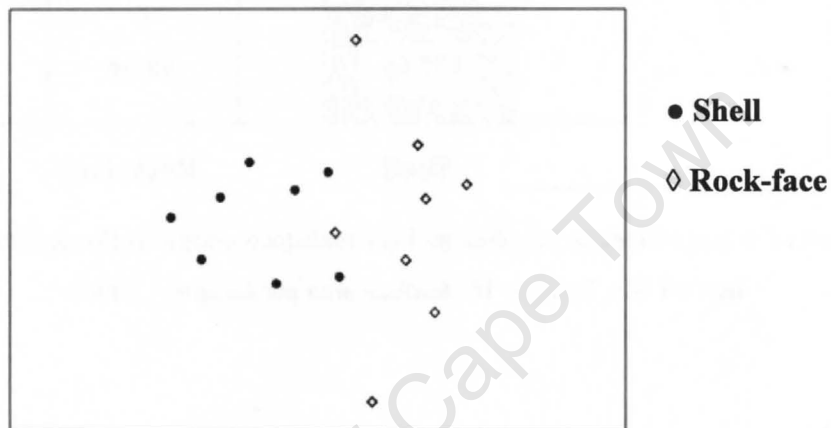


Fig. 10. Two-dimensional MDS ordination of communities on abalone shells and rock-face at Danger Point (Area A). Each symbol represents a sample. Total $n=16$. (Stress = 0.16).

3.4.2 Diversity index

Simpson's index of diversity ($1 - D$) for both abalone shell (0.9667) and rock-face (0.979) was high.

3.4.3 Average biomass per substrate

Average biomass was higher in shell samples than rock-face samples, but not significantly so (t -value=1.170, $df=14$, $p=0.261$) (Fig. 11).

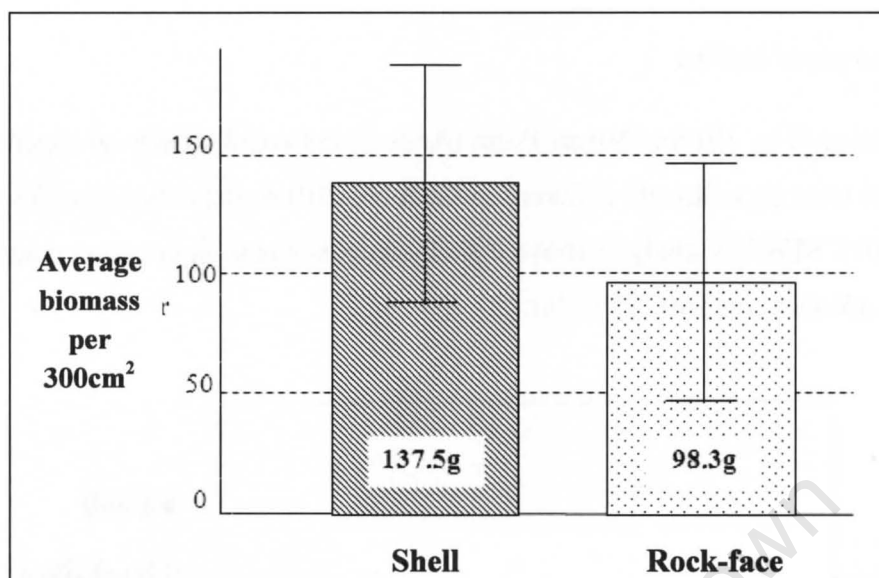


Fig. 11. Bar graph of average biomass per shell and per rock-face sample at Danger Point (Area A). Error bars = 1 SD. Total n=16. Surface area per sample = 300cm².

3.4.4 Average biomass per species

SIMPER comparisons revealed that three species - *Mesophyllum engelhartii*, *Arthrocardia flabellata* and *Gelidium reptans* accounted for more than 80% of similarity within shell samples (Fig. 12). *Heydrichia woelkerlingii*, *Arthrocardia flabellata*, *Cymadusa filosa* and *Nereis* spp. accounted for 80% of similarity within rock-face samples. *Mesophyllum engelhartii*, *Heydrichia woelkerlingii*, *Arthrocardia flabellata* and *Cymadusa filosa* contributed the most to the dissimilarity between the shell and rock-face samples.

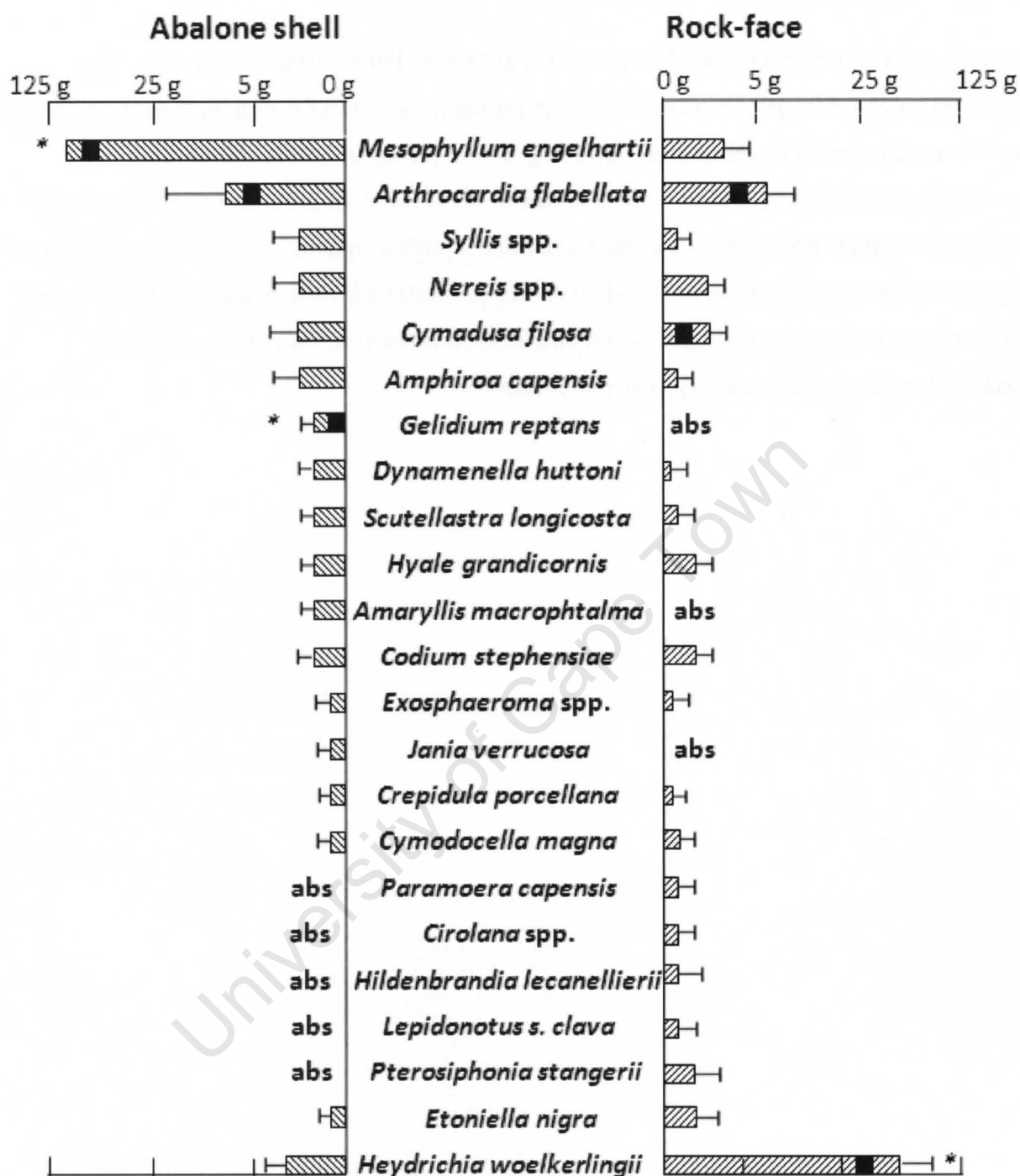


Fig. 12. Average biomass of species found in shell and rock-face samples at Danger Point (Area A). Data 4^{th} root transformed. Black bars indicate characteristic species accounting for 80% of biomass. *** $P < 0.0001$ signif. level, ** $P < 0.001$ signif. level, * $P < 0.05$ signif. level. Error bars (+ 1 SE); abs = absent.

3.4.5 Frequency (%) occurrence of algal species

12 algal species were found on *H. midae* shells at Danger Point (Area A) (Fig. 13). The encrusting algae, *Mesophyllum engelhartii*, and upright algae *Amphiroa flabellata*, and *Gelidium reptans* predominated in abundance, occurring at a frequency of ≥ 50 %. *Heydrichia woelkerlingii* (90 %) and *Arthrocardia flabellata* (70 %) were the most common algae in the rock-face samples. Rhodophyta was the predominant phylum providing the four most common algae. Five species of algae were found on *H. midae* shells (at ≥ 10 % frequency) but were not present in rock-face samples: *Gelidium reptans*, *Jania verrucosa*, *Polyopes constrictus*, *Endarachne binghamiae* and *Leptophytum foveatum*.

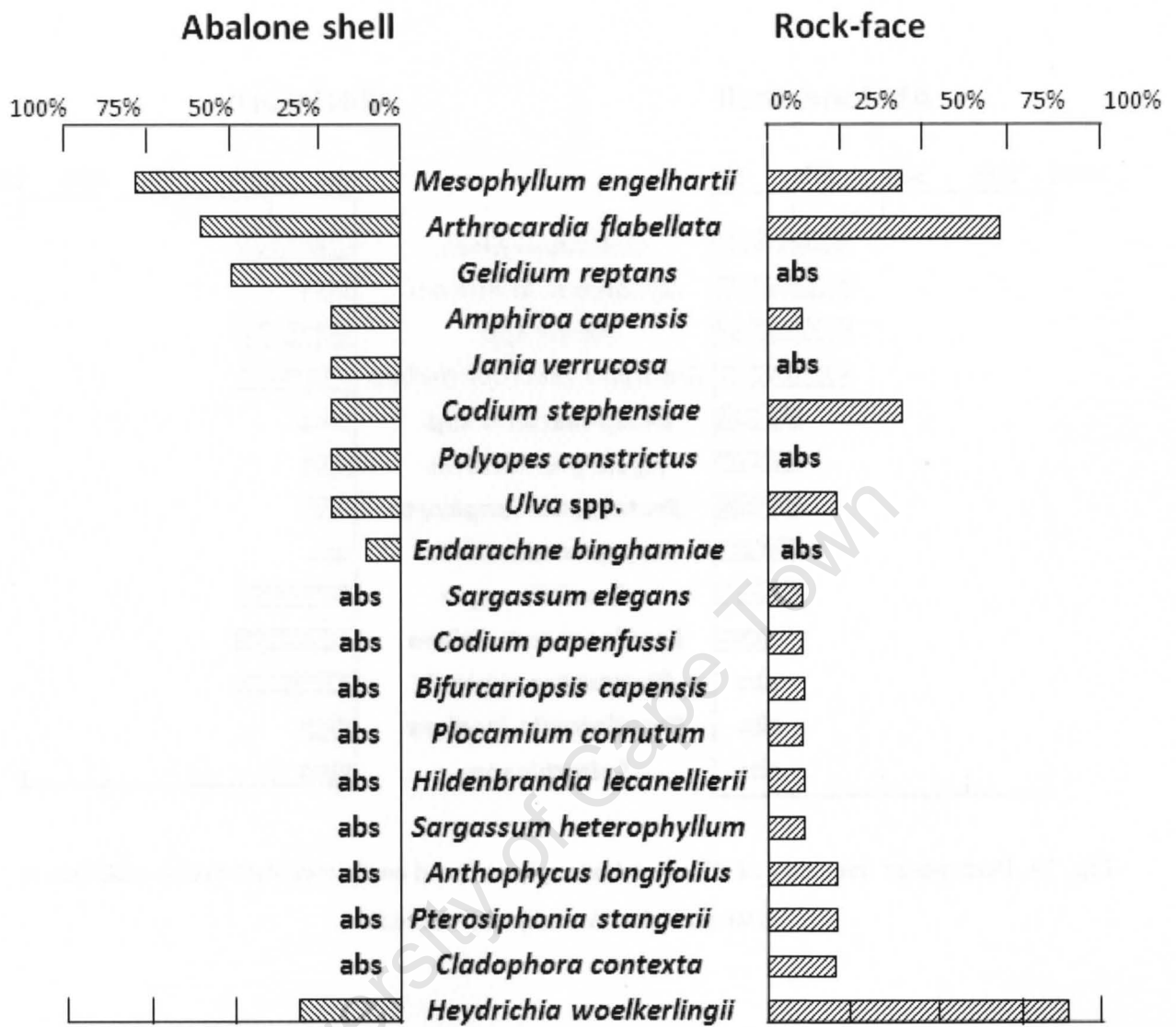


Fig. 13. Percentage frequencies of algal species found on abalone shell versus rock-face at Danger Point (Area A). abs = absent.

3.4.6 Frequency (%) occurrence of invertebrate species

10 invertebrate species were found on *H. midae* shells versus eleven on rock-face at Danger Point (Fig. 14). No invertebrate species occurred on more than half the samples from either shell or rock-face.

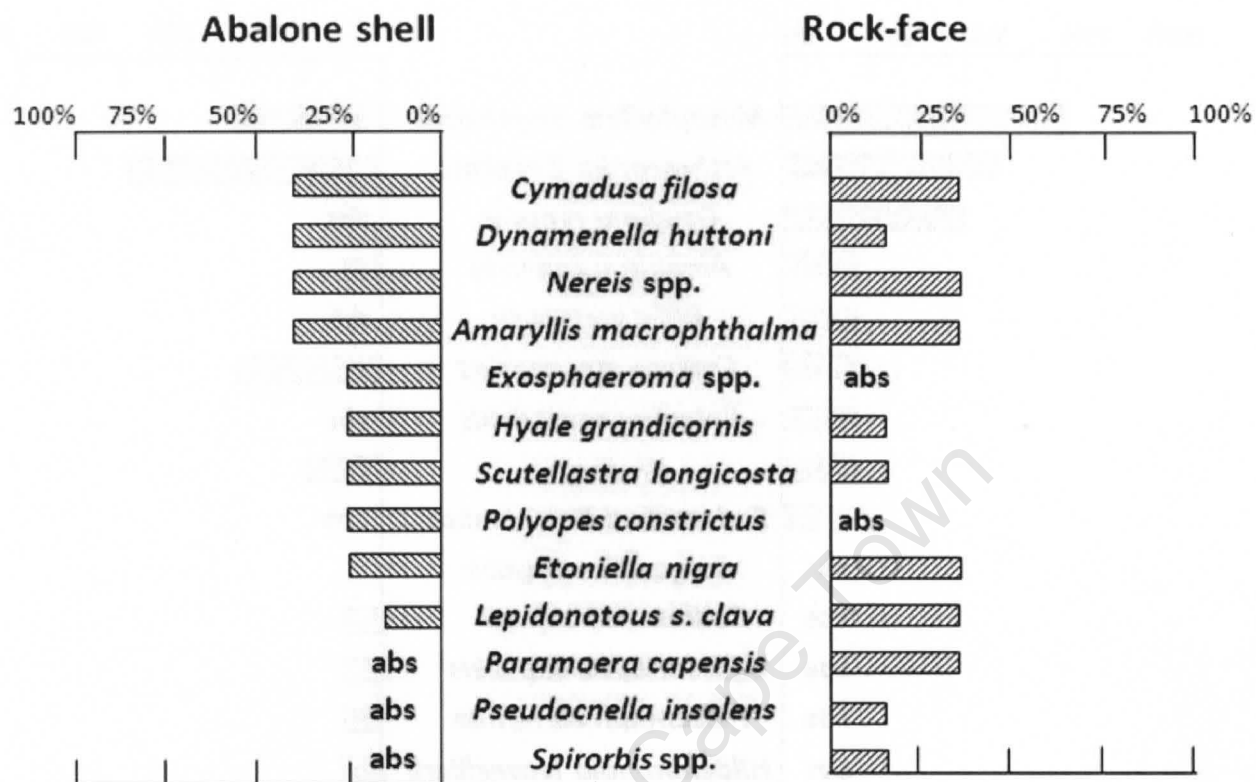


Fig. 14. Percentage frequency of all invertebrate species found on abalone shell versus rock-face at Danger Point (Area A). abs = absent.

3.5 Danger Point (Area B)

3.5.1 Multi-dimensional scaling

The MDS ordination for Danger Point (Area B) showed the shell communities tightly cornered within, and significantly different from, the more diffusely-spaced rock-face communities (ANOSIM, $R = 0.15$, $p = 0.039$) (Fig. 15). SIMPER analysis showed shell samples had a higher percentage similarity (41.98 %) than rock-face samples (26.01 %).

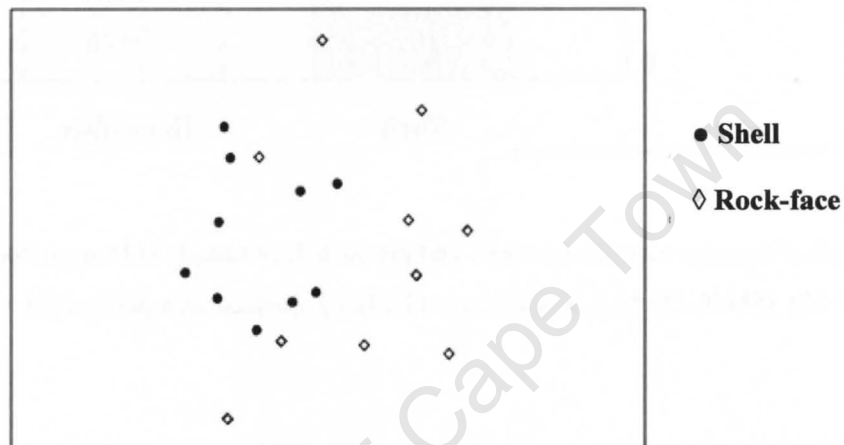


Fig. 15. Two-dimensional MDS ordination of community data found on abalone shells and rock-face at Danger Point (Area B). Each symbol represents a sample. Total $n=20$ (Stress = 0.23).

3.5.2 Diversity index

Simpson's index of diversity ($1 - D$) for both abalone shell (0.9627) and rock-face (0.9318) was high.

3.5.3 Average biomass per substrate

Average biomass was significantly higher in shell samples than rock-face samples (t -value=2.572, $df=18$, $p=0.019$) (Fig. 16). Only *Mesophyllum engelhartii* had a higher biomass in shell communities (Fig. 12).

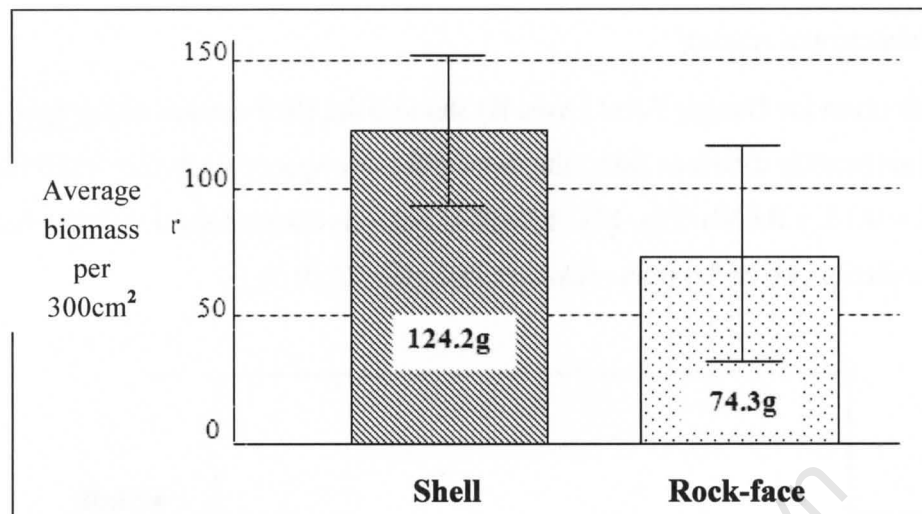


Fig. 16. Bar graph of average biomass per shell and per rock-face sample at Danger Point (Area A). Error bars = 1 SD (Shell ± 29.08 g, Rock-face ± 45.126 g). Surface area per sample = 300 cm².

3.5.4 Average biomass per species

SIMPER comparisons showed that four species, *Mesophyllum engelhartii*, *Arthrocardia flabellata* and *Hyale grandicornis* and *Pterosiphonia stangerii* accounted for around 80 % of similarity within shell samples while *Hyale grandicornis*, *Heydrichia woelkerlingii*, *Arthrocardia flabellata*, *Mesophyllum engelhartii*, *Cymadusa filosa* and *Cirolana* spp. accounted for 80 % of similarity within rock-face samples (Fig. 17). *Mesophyllum engelhartii*, *Arthrocardia flabellata*, *Heydrichia woelkerlingii* and *Pterosiphonia stangerii* contributed the most to the dissimilarity between the shell and rock-face samples.

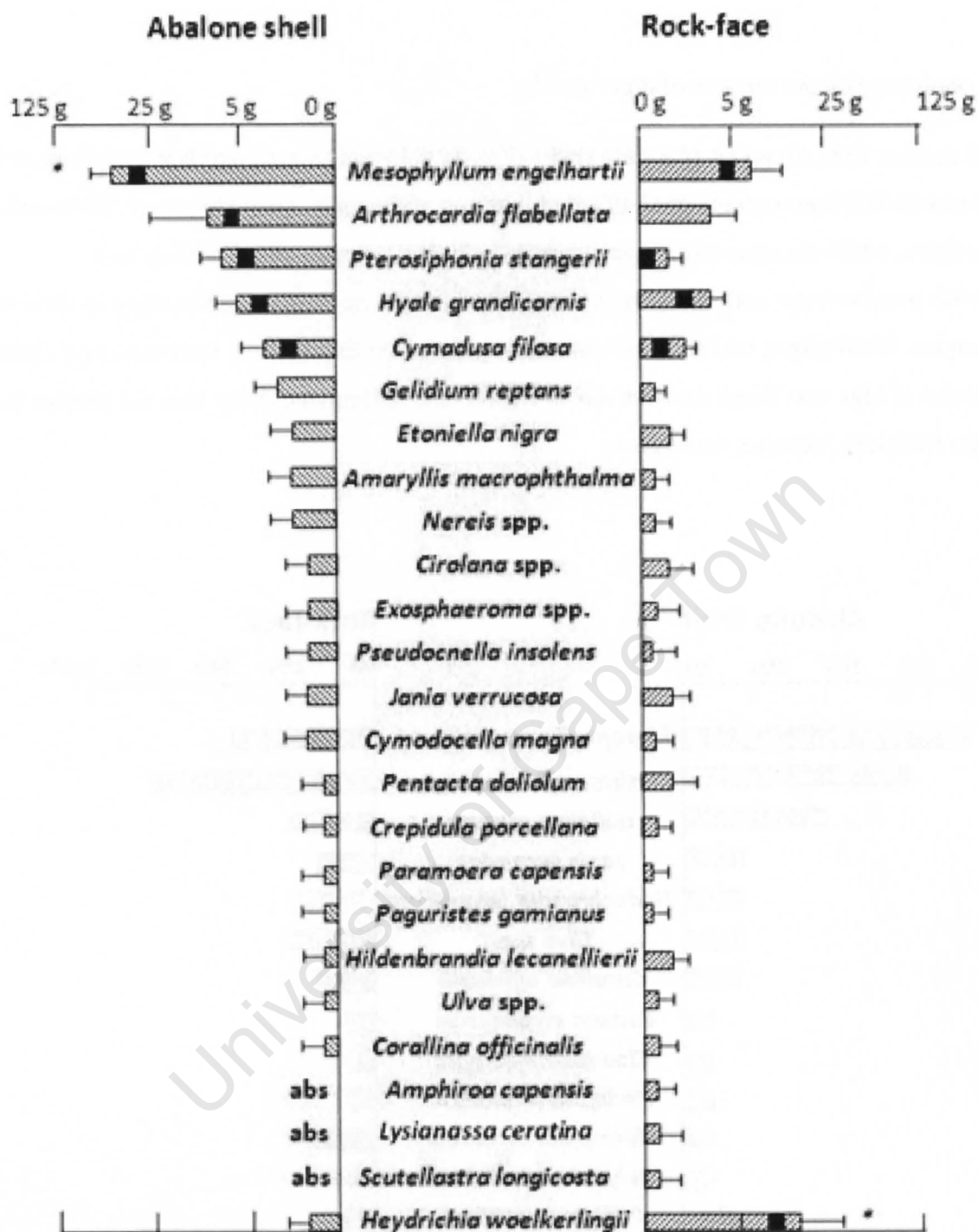


Fig. 17. Average biomass of species found in shell and rock-face samples at Danger Point (Area B). Data 4^{th} root transformed. Black bars indicate characteristic species accounting for 80 % of biomass. *** $P < 0.0001$ signif. level, ** $P < 0.001$ signif. level, * $P < 0.05$ signif. level. Error bars (+ 1 SE); abs = absent.

3.5.5 Frequency (%) occurrence of algal species

14 algal species were found on *H. midae* shells (Fig. 18). *Mesophyllum engelhartii*, *Arthrocardia flabellata* and *Gelidium reptans* predominated in terms of diversity, occurring in all, 80 % and 50 % of samples, while the other twelve occurring in ≤ 20 %. *Arthrocardia flabellata* and *Heydrichia woelkerlingii* and *Mesophyllum engelhartii* were the most common algae in the rock-face samples. Rhodophyta was the predominant phylum providing the five most common algae. One species of alga was found on *H. midae* shells (at ≥ 10 % frequency) that was not present in rock-face samples: *Polyopes constrictus*.

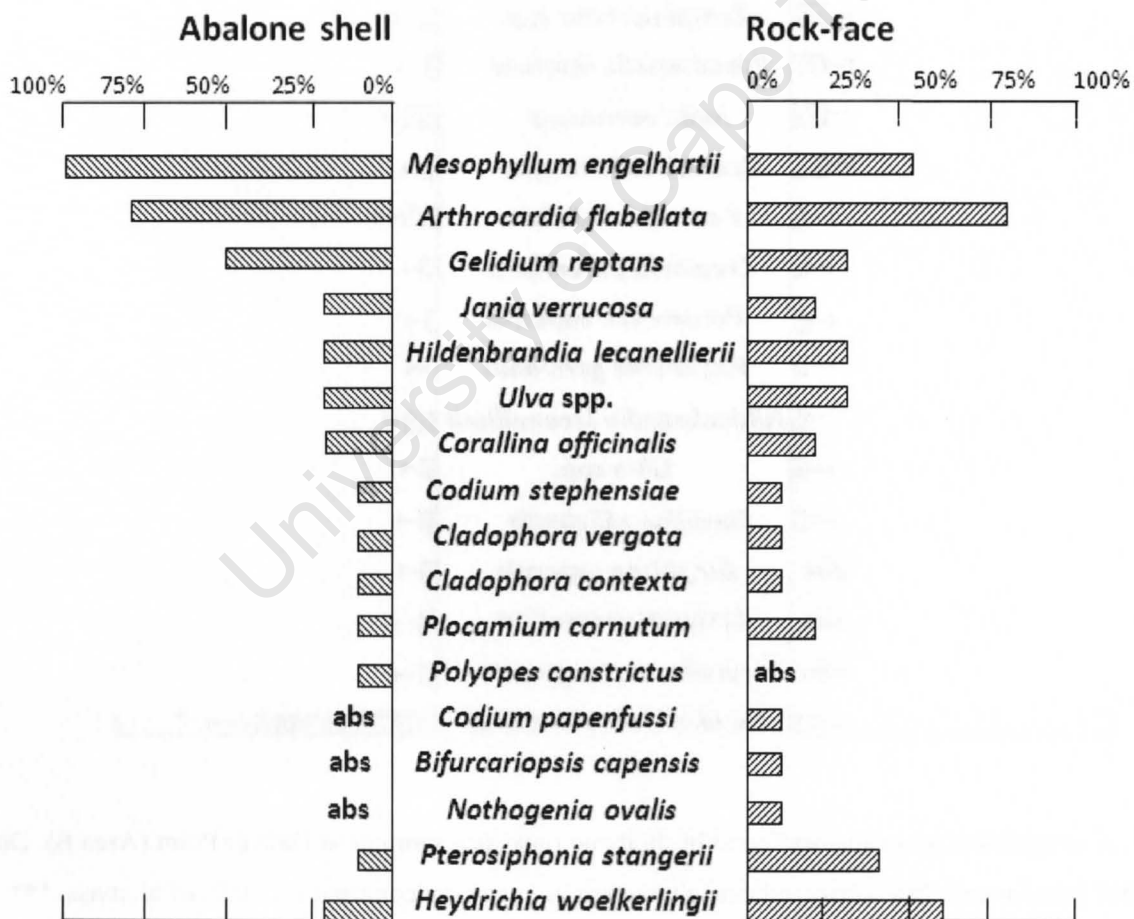


Fig. 18. Frequency (%) bar graph of algal species found on abalone shell versus rock-face at Danger Point (Area B). abs = absent.

3.5.6 Frequency occurrence of invertebrate species

14 invertebrate species were found on both *H. midae* shells and rock-face samples. (Fig. 19).

Two species occurred at a higher than 50 % frequency.

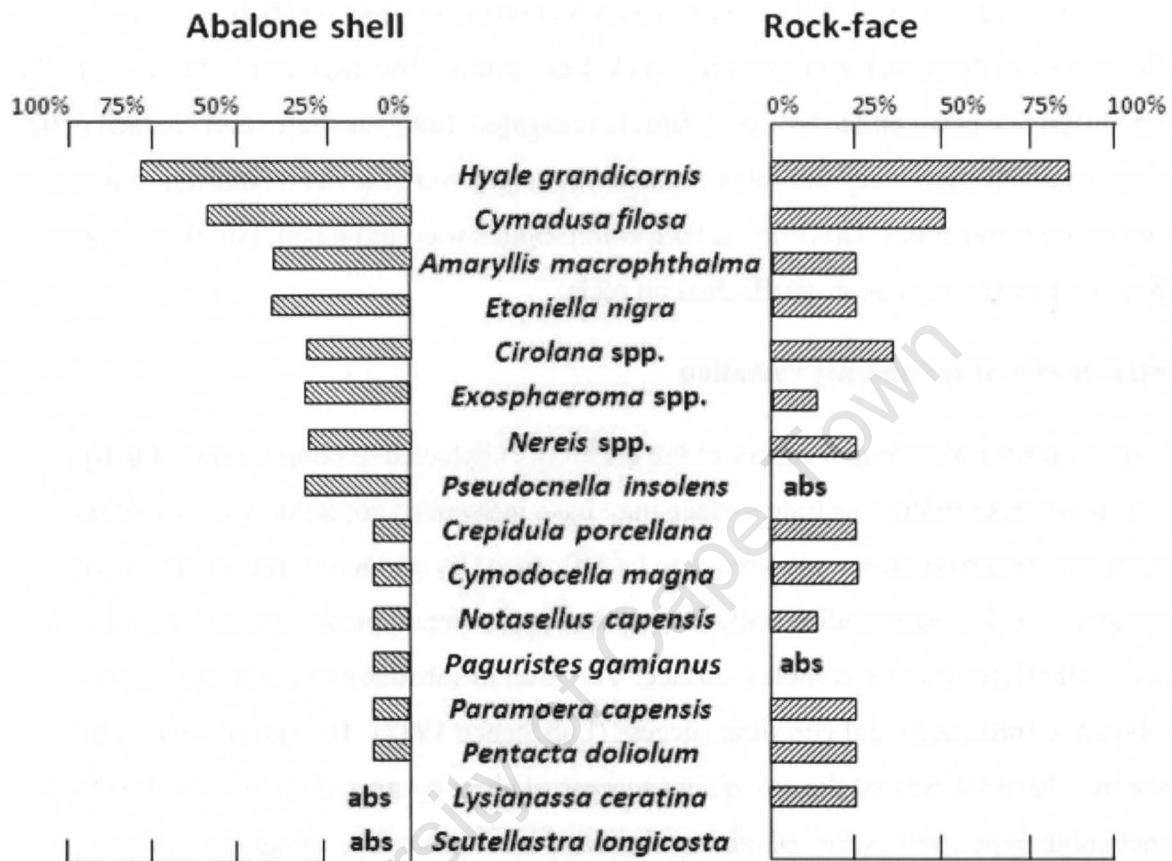


Fig. 19. Percentage frequencies of all invertebrate species found on abalone shell versus rock-face at Danger Point (Area B). abs = absent.

4. Discussion

This study revealed that algal and invertebrate communities' resident on abalone shell differed significantly from those on the surrounding rock-face surface. The algal communities were the primary difference between the two substrates investigated. Both substrates had characteristic but differing dominant encrusting and foliar algae. Foliar algae were the main contributor to overall biomass on both substrates. Diversity in both communities was equivalent, but biomass was significantly greater on abalone shells than on rock.

Potential causes of community variation

There are a number of potential causes of the differences detected in communities. Firstly, physical differences in the substrate surface may have influenced community composition. Algae, as a substrate coloniser, are known to be influenced by surface texture (Dudley and D'Antonio 1991). The surrounding rock-face surface areas were typically smooth whereas the abalone shell offered a more complex surface. Variation in substratum microtopography has been shown to influence algal germling success (Lubchenco 1983). The ridged shell of the abalone may have influenced the colonising success of algae by providing increased surface area and anchorage opportunities for colonising algae and more protective refugia from grazing.

Secondly, hydrodynamic forces can influence community composition. Physical disturbance has been shown to affect the growth success of algae (Airolidi 1998). Additionally, wave action can be an important determinant of algal growth and differing levels of disturbance can influence the order of succession (Sousa 1979). In dense aggregations, abalone may be more favourable to particular algae by providing increased protection from hydrodynamic forces (Barnes 2000, Lauzon-Guay and Scheibling 2007). However, given that all samples were taken from areas of equivalent depth and exposure, physical disturbance is unlikely to drive the differences in composition between shells and rock-face.

Thirdly, the growth of the abalone shell may have affected community composition. Abalone shells increase in size with time, and theoretically this could provide for a variety of stages of succession on a single shell. The centre of the shell forms first and grow outwards. One might expect the younger parts of the abalone shell to have a different composition of algal colonisers

from older portions. For instance, the central part of the abalone shell was found to be dominated consistently by foliar algae whilst the lower and leading younger edges usually had low growing red and encrusting algae.

Finally, there are also biological forces that can influence algal community composition. Grazing can affect algal success and can have an impact upon the community (Lubchenco 1983).

Anecdotal evidence suggests abalone react to the presence of grazers and may impede them from mounting their shells. This may reduce the number of grazers on their shell and thus effect the level of grazing. A number of large grazers were found exclusively on shells but 60% occurred exclusively on rock, indicating less grazing pressure on shells (See Appendix). This could explain why whilst diversity was found to be roughly equivalent on both surfaces, biomass was higher on abalone shells. Additionally, interactions between fish, amphipod and algae have been shown to affect algal community composition (Duffy and Hay 2000).

Determining causes of variation in marine communities is evidently very difficult. Steneck and Dethier (1994) contends that using functional aspects of algal morphology and anatomy can provide insight into benthic community patterns. Foliar algae thrive in high productivity environments which allows for growth of large stands of algae whereas encrusting corallines are far more tolerant of low productivity conditions. However, this aspect does not help us delineate between the two substrates as both had a single dominant foliar and encrusting algae, and instead attests that both were subject to similar depth and light conditions.

Ultimately both substrata possessed similar functional groups, but differed in species composition. Ecological competition theory predicts that the one species best able to utilize the limited resource, such as space, will outcompete other species (Tilman 1977). With respect to biomass production, foliar algae were always dominant. However, foliar and encrusting algae are not necessarily always in competition; indeed, the presence of foliar algae can, in some cases, aid the growth of encrusting algae (Underwood 2006). And so the question of why abalone shells support different algal compositions from the rock-face remains unanswered. It is likely a combination and interaction of the potential causes previously stated, and issues not considered. This leads us to the importance of this diversity and the implications of abalone loss for ecosystem diversity. Beyond the variation seen in resident communities, it is clear that abalone shell represent areas of distinct diversity.

Conservation implications and consequences

From a conservation perspective, there are issues that arise from the continued loss of the abalone. On an ecological level, the role of abalone as grazers is unclear. Research has shown they consume a wide variety of macroalgae as well as polychaetes, amphipods, hydrozoans and seagrass (Guzman *et al.* 2003). The impact of grazer loss from an ecosystem can have considerable consequences for ecosystems functioning (O'Connor and Crowe 2005). However, the abalones' primary mode of feeding is by trapping drifting kelp and so they are unlikely to have an impact on living algae (Barkai and Griffiths 1986, Day and Branch 2002a). More pertinent to this research is that abalone are unique substrate providers. The abalone shell and surrounding rock-face support similar levels of richness but their communities are very different, so that abalone contribute to an increase in beta diversity. Loss of abalone therefore removes a distinct habitat and reduces diversity. It is difficult to know what potential impacts this loss may have on the wider ecosystem. For example, particular types of encrusting coralline algae are known to be important for settlement of abalone larvae. The shells and rock samples supported different species of encrusting corallines, with unknown repercussions for larval settlement.

The future for abalone

A ban on abalone fishing was enacted on November 1 2007 in an effort to prevent its commercial extinction (Legal Brief 2007). However, it has become clear that the ban has done little to curtail the original problem of poaching. Despite the perilously low stock levels, the abalone fishing will be partially re-opened along a small stretch of the Western Cape seaboard for factories once the Fisheries Ministry announces new quotas in February 2010. As of now, the scientific and managerial thinking behind this decision is unclear. With only two years having passed since the ban was implemented, this about turn would appear to be socio-economically driven and not informed by any biological factors. Understandably it is a difficult task to defend the entire South African coastline from poachers with limited funding and limited capacity. It can only be hoped that some of the profits from this partial reopening of the fishery make their way back into the management of this dwindling resource.

5. Conclusion

This research supports the hypothesis that abalone shells host distinct communities. Whilst there is no evidence to suggest that they are more diverse, it is clear that abalone are hubs of distinctive diversity. In the marine environment, discrete and geographically tiny areas are clearly able to sustain a large amount of biological diversity. Consequently, the widespread loss of abalone has broader consequences which demands further investigation, and this research has underscored the need for conservation of abalone for biodiversity reasons over and above the need to manage them as a commercial resource.

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Acknowledgements

I would like to thank Professor George Branch for taking me on as a student and supporting my efforts to complete this project. I would also like to thank Laura Blamey, Debbie Robertson-Andersson, Rob Anderson, Gavin Maneveldt for all their help and Gilly Smith for all assistance throughout my masters. I would also like to thank the entire Zoology Department, which was a great place to learn and to spend time.

A special thanks to all the divers who gave their time over the past year but especially to Andrea Plos for her tireless efforts to help me get the abalone, and George du Plessis for technical support. And where would I be without my classmates, now good friends, Michael, Janine, and Will.

Funding was generously provided by the NRF, the Andrew Mellon Foundation and the Marine Biology Research Centre. Funding was also provided by my wonderful parents and amazing sister, without whom I no doubt would be poorer in mind as well as in pocket.

Appendix – Species list

The following is a complete list of species found on harvested abalone and sampled rock-face at both Cape Point and Danger Point (Area's A & B).

Flora

Chlorophyta	<u>Shell</u>	<u>Rock</u>	<u>Both</u>
<i>Cladophora contexta</i>			X
<i>Cladophora flagelliformis</i>	X		
<i>Cladophora radiosa</i>	X		
<i>Cladophora sericea</i>	X		
<i>Codium papenfussi</i>			X
<i>Codium stephensiae</i>			X
<i>Ulva</i> spp.			X
Phaeophyta			
<i>Anthophycus longifolius</i>		X	
<i>Bifurcariopsis capensis</i>			X
<i>Dictyota</i> cf. <i>dicotama</i>	X		
<i>Endarachne binghamiae</i>			X
<i>Ecklonia maxima</i>			X
<i>Sargassum elegans</i>		X	
<i>Sargassum heterophyllum</i>		X	
Encrusting algae			
<i>Heydrichia woelkerlingii</i>			X
<i>Hildenbrandia lecanellierii</i>			X
<i>Leptophytum foveatum</i>	X		
<i>Mesophyllum engelhartii</i>			X

Rhodophyta

<i>Amphiroa capensis</i>			X
<i>Arthrocardia flabellata</i>			X
<i>Centroceras clavatum</i>		X	
<i>Cheilosporum sagittatum</i>	X		
<i>Cheilosporum cultratum</i>	X		
<i>Corallina officinalis</i>			X
<i>Gelidium reptans</i>			X
<i>Heterosiphonia</i> spp.			X
<i>Jania verrucosa</i>			X
<i>Nothogenia ovalis</i>		X	
<i>Polyopes constrictus</i>	X		
<i>Plocamium cornutum</i>			X
<i>Pterosiphonia stangerii</i>			X
<i>Rhodymenia capensis</i>	X		

Fauna

Porifera

<i>Halichondria capensis</i>		X	
<i>Haliclona</i> spp.			X
<i>Hymeniacidon</i> spp.		X	
<i>Polymastia mammilaris</i>		X	
<i>Sycon</i> spp.		X	

Hydrozoa

<i>Aglaophenia pluma</i>	X
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Polychaeta

<i>Ceratonereis</i> spp.	X		
<i>Euphrosine capensis</i>		X	
<i>Lepidonotus semitectus clava</i>			X

	<u>Shell</u>	<u>Rock</u>	<u>Both</u>
<i>Lysidice natalensis</i>			X
<i>Lumbrineris coccinea</i>		X	
<i>Megalomma quadrioculatum</i>		X	
<i>Nereis</i> spp.			X
<i>Onuphis</i> spp.		X	
<i>Platynereis dumerilii</i>			X
<i>Pherusa monroi</i>			X
<i>Syllis</i> spp.			X
<i>Spirobis</i> spp.			X
<i>Terebella pterochaeta</i>			X
<i>Timarete capensis</i>			X
Polyplacophora			
<i>Ischnochiton bergoti</i>		X	
<i>Ischnochiton oniscus</i>			X
Gastropoda			
<i>Afrocominella elongata</i>		X	
<i>Burnupena cinta</i>			X
<i>Calopia</i> spp.	X		
<i>Clionella sinuata</i>		X	
<i>Crepidula dilatata</i>		X	
<i>Crepidula porcellana</i>			X
<i>Cymbula miniata</i>			X
<i>Dendropoma corallinaceus</i>		X	
<i>Etoniella nigra</i>			X
<i>Fissurella mutabilis</i>		X	
<i>Gibbula capensis</i>		X	
<i>Gibbula zonata</i>		X	
<i>Scutellastra barbara</i>			X

	<u>Shell</u>	<u>Rock</u>	<u>Both</u>
<i>Scutellastra longicosta</i>			X
<i>Tricolia neritina</i>			X
<i>Turbo cidaris</i>		X	
Bivalvia			
<i>Aulacomya ater</i>	X		
<i>Gregariella petagnae</i>	X		
<i>Kellya rubra</i>	X		
<i>Mytilus galloprovincialis</i>	X		
<i>Perna perna</i>			X
Isopoda			
<i>Cirolana</i> spp.			X
<i>Cymodocella magna</i>			X
<i>Dynamenella dioxius</i>			X
<i>Dynamenella huttoni</i>			X
<i>Dynamenella scabricula</i>			X
<i>Exosphaeroma</i> sp.			X
<i>Glyptidotea lichtensteni</i>		X	
<i>Jaeropsis stebbingi</i>			X
<i>Notasellus capensis</i>	X		
<i>Paridotea fucicola</i>		X	
<i>Parisocladus perforatus</i>		X	
Amphipoda			
<i>Amaryllis macrophthalma</i>			X
<i>Ampelisca palmata</i>			X
<i>Ampelisca excavata</i>			X
<i>Aora holmesi</i>		X	
<i>Caprella</i> spp.	X		

	<u>Shell</u>	<u>Rock</u>	<u>Both</u>
<i>Cyproidea ornata</i>	X		
<i>Cymadusa filosa</i>			X
<i>Hyale grandicornis</i>			X
<i>Lysianassa ceratina</i>			X
<i>Monocorophium acherusicum</i>			X
<i>Paramoera capensis</i>			X
<i>Temnophilias capensis</i>			X
Tanaidacea			
Tanaids			X
Anomura			
<i>Paguristes gamianus</i>			X
Brachyura			
<i>Pilumnoides</i> spp.		X	
<i>Pilumnus hirsutus</i>			
Ophiuroidea			
<i>Amphiolus integer</i>	X		
<i>Amphipholis squamata</i>			X
<i>Ophiactis carnea</i>	X		
<i>Ophiothrix fragilis</i>		X	
Echinoidea			
<i>Parechinus angulosus</i>		X	
Holothuroidea			
<i>Pentacta doliolum</i>			X
<i>Pseudocnella sykion</i>		X	

	<u>Shell</u>	<u>Rock</u>	<u>Both</u>
<i>Pseudocnella insolens</i>			x
Ascidacea			
<i>Ascidia</i> spp.			x
<i>Diplosoma listerianum</i>		x	

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